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SPECIFICATION

LIQUID CRYSTAL DISPLAY

[Technical Field]

The present invention relates to a liquid crystal display (that is, a liquid crystal display module), and more particularly to a reflection-type liquid crystal display device which displays images by reflecting an external light.

[Background of the Invention]

In a current sophisticated information society, a request for getting access to necessary information at any time and anywhere is high and hence, a demand for a portable type information processing device 47 such as a device shown in Fig. 16 has been increasing.

The portable-type information processing device 47 is required to be small-sized and light-weighted, to have a thin thickness, and to be driven for a long time by a battery.

Accordingly, as a display device 46 of the portable-type information processing device 47, a reflection-type liquid crystal display 46 is optimal in view of reasons that a small-sized, light-weighted and thin display device can be manufactured, an auxiliary illumination is unnecessary and hence, a power consumption can be reduced when an external light such as sunlight is available or the like.

However, even these days, the request for making the portable-type

information processing device 47 small-sized, thin and light-weighted is strong and hence, the request for making the reflection-type liquid crystal display device 46 small-sized, thin and light-weighted and is also becoming strong correspondingly.

It is an object of the present invention to provide a thin liquid crystal display.

It is another object of the present invention to provide a light-weighted liquid crystal display.

It is another object of the present invention to provide a small-sized liquid crystal display.

It is another object of the present invention to provide a liquid crystal display which has a simple structure and exhibits good display characteristics.

It is another object of the present invention to provide a liquid crystal display which has a simple structure and can obtain a high contrast display.

Further, it is another object of the present invention to provide a reflection-type liquid crystal display which has a simple structure and can obtain a high reflectance for an external light.

Further, it is another object of the present invention to provide a reflection-type liquid crystal display which has a simple structure and can recognize a display even in a dim place.

Further, it is another object of the present invention to provide a liquid crystal display which has a simple structure and exhibits a little power consumption.

It is another object of the present invention to provide a liquid crystal

display device which can be manufactured using a small number of members.

It is another object of the present invention to provide a liquid crystal display device which can be manufactured easily.

Further, it is still another object of the present invention to reduce the cost of a liquid crystal display.

Further, with respect to the quality of the display of the reflection-type liquid crystal display device, there is still a room for improvement compared to a transmission-type liquid crystal display.

Accordingly, it is another object of the present invention to provide a reflection-type liquid crystal display which exhibits a high contrast in display.

Further, it is another object of the present invention to provide a reflection-type liquid crystal display which exhibits a high reflectance and a high light utilization efficiency.

As a known example of the reflection-type liquid crystal display which is provided with an auxiliary illumination device, there has been a device disclosed in Japanese Laid-open Patent Publication 326515/1998. However, the above-mentioned known example fails to describe the constitution of an light diffusing layer, the relationship among optical axes of various kinds of optical films and an optimum numerical values of retardation ($\Delta n \cdot d$).

[Disclosure of the Invention]

In a reflection-type liquid crystal display, a light diffusing film is

used for improving the viewing angle characteristics of display.

Fig. 2 is a view showing a cross-section of the reflection type liquid crystal display which uses the light diffusing film. Since respective numerals are identical with numerals used in Fig. 1 which are explained later, the detailed explanation of the numerals is omitted.

An external light L1 advancing toward a liquid crystal display 46 passes a specific pixel electrode 4a and is reflected on a reflecting layer 2 thus forming a reflection light L2 and this reflection light L2 irradiated to the outside of the liquid crystal display 46 after passing a light diffusing film 12a.

The reflection light L2 which has passed the light diffusing film 12a generates diffused light L3 which is diffused in various directions.

Accordingly, an observer who observes the liquid crystal display from an arbitrary direction can recognize the display by watching the diffused light L3.

To the contrary, as shown in Fig. 3, in a reflection-type liquid crystal display which has no light diffusing film, a reflection light L2 is irradiated only in a specific direction.

Accordingly, unless the reflection-type liquid crystal display is not provided with a member such as the light diffusing film 12a which scatters light in various directions, it is difficult for an observer who observes the liquid crystal display 46 at a position which is away from a passage of the reflection light L2 to recognize the display.

In this manner, with respect to the reflection-type liquid crystal display, the member such as the light diffusing film 12a which scatters light

is inevitable to facilitate the observation of the display.

However, when the light diffusing film having a thick thickness is used as the member for scattering light, it becomes difficult to make the liquid crystal display small-sized, thin and light-weighted.

Further, with respect to the display characteristics of the reflection-type liquid crystal display such as contrast, reflectance and the like, the request for the further improvement of the display characteristics is increasing these days.

To solve the above-mentioned tasks, according to the present invention, as shown in Fig. 1a and Fig. 1b, a light diffusing layer 11a which is provided to a display part of a liquid crystal display is constituted of an adhesive agent 17 and light diffusing material 16 which has a refractive index different from that of the adhesive agent 17.

Further, to enhance the display quality of the reflection-type liquid crystal display, as shown in Fig. 6, the reflection spectral characteristics 34 of a light reflecting layer 2 and the transmission spectral characteristics 35a of the light diffusing layer 11a in the liquid crystal display panel are optimized.

Further, to enhance the display quality of the reflection-type liquid crystal display, the retardations (product of a value Δn of refractive index anisotropy and the thickness d of a layer having the refractive index anisotropy, also referred to as $\Delta n \cdot d$) of the liquid crystal display panel and respective optical retardation plates are optimized.

Further, to enhance the display quality of the reflection-type liquid crystal display, as shown in Fig. 7, the relationship among optical axes

(elongation axis, polarization axis) 38 of a polarizer 12b, an optical axis 39 of a first optical retardation plate 12c, an optical axis 40 of a second optical retardation plate 12d, an incident-light-side orientation axis (an orientation axis of a liquid crystal layer 9 at a side which is in contact with a second substrate 5 or a second orientation axis of the liquid crystal layer) 37 of the liquid crystal display panel and an irradiation-light-side orientation axis (an orientation axis of the liquid crystal layer 9 at a side which is in contact with the first substrate 1 or a first orientation axis of the liquid crystal layer) 36 is optimized in such a manner that an angle made by the optical axis 40 of the second optical retardation plate 12d which is in contact with the second substrate 5 and the orientation axis 36 of the irradiation-light-side liquid crystal layer 9 is set in a range of 30° to 80°, an angle made by the optical axis 39 of the first optical retardation plate 12c which is in contact with the polarizer 12b side and the orientation axis 36 of the irradiation-light-side liquid crystal layer 9 is set in a range of 60° to 130°, an angle made by the optical axis 38 of the polarizer 12b and the orientation axis 36 of the irradiation-light-side liquid crystal layer 9 is set in a range of 70° to 150°, an angle made by the orientation axis 36 of the irradiation-light-side liquid crystal layer 9 and the orientation axis 37 of the incident-light-side liquid crystal is set to not less than 240 degree, the retardation $\Delta n \cdot d$ of the liquid crystal layer 9 is set to 0.7 μm to 0.95 μm, the retardation $\Delta n \cdot d$ of the second optical retardation plate 12d is set to 130 nm to 250 nm, and the retardation $\Delta n \cdot d$ of the first optical retardation plate 12c is set to 380 nm to 500 nm.

According to the present invention, since the light diffusing layer 11a which is provided to the display part of the liquid crystal display is

constituted of the adhesive agent 17 and the light diffusing material 16 which has the refractive index different from that of the adhesive agent 17, the light diffusing film becomes unnecessary so that the liquid crystal display can be made thin, small-sized and light-weighted.

Further, according to the present invention, as shown in Fig. 6, by making the transmission spectral characteristics 35a of the light diffusing layer 11a flat as in the case of the reflection spectral characteristics 34 of the light reflecting layer 2 of the liquid crystal display panel, the reflectance characteristics of the liquid crystal display can be improved. Accordingly, it becomes possible to provide the liquid crystal display which exhibits the favorable light utilization efficiency.

Further, according to the present invention, by optimizing the retardations of $\Delta n \cdot d$ of the liquid crystal display panel and respective optical retardation plates, it becomes possible to provide the liquid crystal display which exhibits high contrast characteristics.

Further, according to the present invention, by optimizing the relationship among the optical axis 38 of the polarizer 12b, the optical axis 39 of the first optical retardation plate 12c, the optical axis 40 of the second optical retardation plate 12d and the incident-light-side orientation axis 37, and the irradiated-light-side orientation axis 36 of the liquid crystal display panel, even when the irregularities exist in the retardations of the first optical retardation plate 12c and the second optical retardation plate 12d, it becomes possible to provide the liquid crystal display having high contrast characteristics.

[Brief Explanation of Drawings]

Fig. 1a is a cross-sectional view of a liquid crystal display according to one embodiment of the present invention and Fig. 1b is an enlarged view of an I portion of Fig. 1a.

Fig. 2 is a cross-sectional view of a reflection-type liquid crystal display using a light diffusing film.

Fig. 3 is a cross-sectional view of a reflection-type liquid crystal display having no light diffusing film.

Fig. 4a to Fig. 4e are views showing an appearance of the liquid crystal display according to one embodiment of the present invention.

Fig. 5a is a cross-sectional view of a portion taken along a line A-A of Fig. 4a and Fig. 5b is a cross-sectional view of a portion taken along a line B-B of Fig. 4a, Fig. 5c is a cross-sectional view of a portion taken along a line C-C of Fig. 4a and Fig. 5d is a cross-sectional view of a portion taken along a line D-D of Fig. 4a.

Fig. 6 is a view showing the spectral characteristics of an adhesive agent containing diffusing material.

Fig. 7 is a view for explaining the angular relationship among an absorption axis of a polarizer, an elongation axis of a first optical retardation plate and an elongation axis of a second optical retardation plate in one embodiment of the present invention.

Fig. 8 is a view showing the change of the contrast ratio of the display of the liquid crystal display for the change of the retardation ($\Delta n \cdot d$) of the optical retardation plate.

Fig. 9 is a view showing the change of the reflectance of an external

light in the liquid crystal display for the change of retardation of the optical retardation plate.

Fig. 10 is a cross-sectional view of a liquid crystal display according to a second embodiment of the present invention.

Fig. 11 is a cross-sectional view of a liquid crystal display according to a third embodiment of the present invention.

Fig. 12 is a cross-sectional view of a liquid crystal display according to a fourth embodiment of the present invention.

Fig. 13 is a cross-sectional view of a liquid crystal display according to a fifth embodiment of the present invention.

Fig. 14 is a cross-sectional view of a liquid crystal display according to a sixth embodiment of the present invention.

Fig. 15 is a cross-sectional view of a liquid crystal display according to a seventh embodiment of the present invention.

Fig. 16 is a perspective view showing an appearance of an information processing device adopting the liquid crystal display of the present invention.

[Best Mode for Carrying out the Invention]

Hereinafter, embodiments of the present invention are explained in detail in conjunction with drawings. In the drawings which will be explained hereinafter, parts which have the identical functions are given same numerals and their repeating explanations are omitted.

<u>First Embodiment</u>

Fig. 1a is a cross-sectional view of a liquid crystal display according

to one embodiment of the present invention and Fig. 1b is an enlarged view of an I portion of Fig. 1a.

In this embodiment, an illumination device which is constituted of a light guide body 13, a linear light source 14 such as a fluorescent lamp, LED or the like and an input device 15 such as a touch panel or the like are mounted on a reflection-type liquid crystal display panel.

On an inner surface of a first substrate 1 which constitutes a lower glass substrate, a reflecting layer 2 made of an aluminum thin film, a protective film 3 which is constituted of an oxidation prevention film made of SiO_2 or the like and a lower electrode (signal electrode) 4 which is constituted of a transparent conductive film such as ITO (Indium Tin Oxide) or the like are formed.

Further, on an inner surface of a second substrate 5 which constitutes an upper glass substrate, color filters 6 in three colors (R, G, B) which are produced by adding dye or pigment in organic resin films, a protective film 7 made of organic material which prevents the mixing of impurities from the color filters 6 into a liquid crystal layer 9 and flattens the inner surface of the second substrate 5 and an upper electrode (scanning electrode) 8 which is formed of a transparent conductive film made of ITO or the like are formed.

Between respective colors R, G, B which constitute the color filters 6, when necessary, a grid-like or a stripe-shaped light shielding film (black matrix) is formed and the protective film 7 is formed on the light shielding film.

The liquid crystal layer 9 which is formed of liquid crystal

composition is inserted between these first and second substrates 1, 5 and is sealed by sealing material 10 such as epoxy resin thus constituting the liquid crystal display panel.

On an outer side (upper side) of the second substrate 5 which constitutes an observer-side substrate of the liquid crystal display panel, a polarizer 12b, a first optical retardation plate 12c and a second optical retardation plate 12d are laminated. Between the second substrate 5, the polarizer 12b, the first optical retardation plate 12c and the second optical retardation plate 12d, adhesive layers 11, 11a which are made of an adhesive agent (for example, epoxy-based or acrylic adhesive agent), tacky adhesive material or the like are provided so as to fixedly secure respective members. Here, the tacky adhesive material means an adhesive agent which can make various kinds of optical films 12 adhered to each other even after these optical films 12 are pealed off after adhering them to each other once. By fixedly securing various kinds of optical films 12 and the liquid crystal display panel to each other using the tacky adhesive agent, even when the optical film 12 is fixedly secured in error, the optical film can be reproduced so that the manufacturing yield of the liquid crystal display can be enhanced.

It is preferable to use the reflecting layer 2 having the specular reflection property from a viewpoint of the reflectance. In this embodiment, an aluminum film is formed by a vapor deposition method. A multi-layered film may be applied to a surface of the reflecting layer 2 to enhance the reflectance and a protective film 3 is formed on a surface of the multi-layered film to prevent the erosion of the reflecting layer 2 and to flatten the surface of the reflecting layer 2.

Here, this reflecting layer 2 is not limited to aluminum and a metal film made of chromium, silver or the like or a non-metallic film may be used as the reflecting layer 2 so long as such a film has a specular reflecting property. Further, the protective film 3 is not limited to the SiO_2 film and may be made of any insulation film which can protect the reflecting layer 2. An inorganic film such as a nitride film of silicon or the like or an organic metallic film such as an organic titanium film or the like or an organic film made of polyimide or epoxy or the like can be used as the protective film 3. Particularly, the organic film made of polyimide, epoxy or the like exhibits the excellent flatness so that the lower electrode 4 which is formed on the protective film 3 can be easily formed. Further, by using the organic metallic film such as organic titanium film or the like as the protective film 3, the lower electrode 4 can be formed at a high temperature so that the wiring resistance of the lower electrode 4 can be reduced.

Over the liquid crystal panel which mounts the laminated optical film 12 thereon, the light guide body 13 and the light source 14 are disposed as the illumination device which is used when the external light is small. The light guide body 13 is formed of transparent resin such as acrylic resin or the like and a printing pattern or uneven surface processing is provided to the observer-side surface (upper surface) of the light guide body 13 to irradiate the light L4 from the light source 14 toward the liquid crystal display panel side.

Further, over the illumination device, the input device 15 such as the touch panel or the like is provided. This input device 15 is constituted such that by pushing a surface of the input device 15 with a rod-like member

having a sharpened tip such as a pen, a finger or the like, a position of a pushed portion is detected and a data signal to be transmitted to a host computer 50 of an information processing device 47 is outputted.

The second substrate 5, the light guide body 13 and the input device of the liquid crystal display panel are fixedly secured by using pressure sensitive adhesive double coated tapes (for example, non-woven fabric impregnated with tacky adhesive agent). With the use of the pressure sensitive adhesive double coated tapes, it becomes possible to perform the peeling-off after the adhesion is once performed and hence, even when the liquid crystal display panel, the illumination device and the input device are fixedly secured by an error, they can be reproduced.

When the illumination and the data inputting are unnecessary, the illumination device and the input device 15 may be eliminated and the illumination device and the input device 15 may be added to the liquid crystal display panel when necessary.

According to this embodiment, the adhesive layer 11a which is sandwiched between the first optical retardation plate 12c and the second optical retardation plate 12d is provided with a light diffusion function. To be more specific, as shown in Fig. 1b, the light diffusing material 16 which has a refractive index different from that of the adhesive agent 17 is mixed into the adhesive agent 17. Since the adhesive agent 17 and the diffusing material 16 are different from each other in the refractive index, the light is scattered in the inside of the adhesive layer 11a. The only condition required here is that the adhesive agent 17 and the diffusing material 16 exhibit the different refractive indices and hence, when epoxy-based resin or

acrylic resin is used as the adhesive agent 17, transparent organic material particles made of polyethylene, polystyrene divinylbenzene or the like or transparent inorganic material particles made of silica or the like can be used as the diffusion material 16. Provided that the refractive index of the adhesive agent 17 is different from that of the diffusion material 16, the above-explained tacky adhesive agent may be used as the adhesive agent 17. In this case, even when the first optical retardation plate 12c is adhered to the second optical retardation plate 12c in error, the first optical retardation plate 12c can be reproduced. By using particles made of transparent inorganic material or organic material as the diffusion material 16, the absorption of the light in the visible light range is small and hence, the reflectance and the spectral characteristics of the liquid crystal display can be improved. Further, when the adhesive agent 17 is made of the organic material, by using particles made of the organic material as the diffusion material 16, the difference in thermal expansion coefficient can be reduced and hence, the occurrence of cracks in the adhesive layer 11a can be eliminated.

When the diffusion material 16 is mixed into the inside of the adhesive agent 17, there may be a case that cracks are more liable to occur in the adhesive layer 11a compared to a case in which only the adhesive agent 17 is used. In this embodiment, however, since the adhesive layer 11a containing the light diffusion material is interposed between the first optical retardation plate 12c and the second optical retardation plate 12d which substantially have the same thermal expansion coefficients, there is no problem that cracks occur in the adhesive layer 11a.

«Principle of Image Display»

The display principle of the liquid crystal display of this embodiment is explained hereinafter.

An external light L1 (incident light) such as sunlight irradiated from various directions passes the input device 15, the light guide body 13, the polarizer 12b which allows only light having a specific polarization axis to pass therethrough, the adhesive layer 11 which is served for fixedly securing the polarizer 12b to the first optical retardation plate 12c, the first optical retardation plate 12c, the adhesive layer 11a having the light diffusion function which is served for fixedly securing the first optical retardation plate 12c to the second optical retardation plate 12d, the second optical retardation plate 12d, the adhesive layer 11 which is served for fixedly securing the second optical retardation plate 12d to the second substrate 5, the second substrate 5, the color filter 6, the upper electrode 8, the liquid crystal layer 9 and the specific pixel electrode (or the specific signal line) 4a and reaches the reflecting layer 2.

The external light L1 which has reached the reflecting layer 2 is reflected to generate a reflection light L2. The reflection light L2 passes a route opposite to that of the incident light L1, that is, the specific pixel electrode 4a, the liquid crystal layer 9, the upper electrode 8, the color filter 6, the second substrate 5, the adhesive layer 11 and the second optical retardation plate 12d which converts the reflection light L2 into light which can easily pass the polarizer 12 by making use of the birefringence effect and reaches the adhesive layer 11a having the light diffusion function.

The reflection light L2 which is incident on the adhesive layer 11a is

scattered in various directions so as to generate scattered light L3. The direct reflection light L2 and the scattered light L3 irradiated from the adhesive layer 11a are emitted to the outside of the liquid crystal display device after passing the first optical retardation plate 12c which compensates for the phase difference which is generated at a point of time that the light passes the liquid crystal layer 9 by making use of the birefringence effect, the adhesive layer 11, the polarizer 12b, the light guide body 13 and the input device 15. The observer can recognize the display controlled by the specific pixel 4a by observing the direct reflection light L2 and the scattered light L3 which are emitted to the outside of the liquid crystal display.

«Adhesive layer having light diffusion function»

In this embodiment, since the adhesive layer 11a which is served for fixedly securing the first optical retardation plate 12c to the second optical retardation plate 12d has the light diffusion function, the observer who is positioned at a location away from an advancing passage of the direct reflection light L2 also can recognize the display by means of the scattered light L3 so that the viewing angle characteristics of the liquid crystal display can be improved.

Further, since the light diffusion film 12a becomes unnecessary, the light liquid crystal display can be made thin, small-sized and light-weighted. Still further, since the light diffusion film 12a becomes unnecessary, the structure of the liquid crystal display can be simplified thus enhancing the productivity.

In this embodiment, it is preferable to use the adhesive layer 11a

having the light diffusion function which has 60 % to 90 % of haze value. The haze value H is expressed by a following formula 1, wherein Tt indicates the total light beam transmittance and Td indicates the diffusion transmittance.

$$H = Tt/Td \times 100 \ldots \qquad \text{formula 1}$$

When the haze value H of the adhesive layer 11a is smaller than 60 %, a quantity of the diffusion light L3 is reduced and hence, the viewing angle characteristics is worsened. Further, when the haze value H of the adhesive layer 11a is larger than 90 %, the light transmittance of the adhesive layer 11a is worsened and hence, the reflectance of the liquid crystal display is reduced.

With the use of the adhesive layer 11a having the light diffusion function as described in this embodiment, by adjusting the difference between the refractive indices of the adhesive agent 17 and the diffusion material 16, the dispersion density of the diffusion material 16 and the particle diameter d of the diffusion material 16, the haze value H can be easily set to an optimum value. Further, in an example in which the epoxy-based adhesive agent or the acrylic adhesive agent is used as the adhesive agent 17 and the transparent beads (spherical shape) made of organic resin such as divinylbenzene or the like is used as the diffusion material 16, by setting the spherical diameter d of the diffusion material 16 in a range of 3 μm to 10 μm, the high contrast which is not less than 6 can be obtained. Further, by matching the transmission spectral characteristics of the adhesive layer 11a having the light diffusion function to the reflection spectral characteristics of the reflecting layer 2, the reflectance of the liquid

crystal display can be enhanced.

Fig. 6 shows the reflection spectral characteristics 34 of the reflecting layer 2, the transmission spectral characteristics 35a of the flat-type light diffusion adhesive layer and the transmission spectral characteristics 35b of the non-flat-type light diffusion adhesive layer.

The reflection spectral characteristics 34 of the reflecting layer 2 in the visible light region exhibits the approximately fixed flat characteristics irrespective of the wavelength of the light.

The transmission spectral characteristics 35a of the flat-type light diffusion adhesive layer is also adjusted to have the substantially fixed flat characteristics in the visible light region.

With respect to the transmission spectral characteristics 35b of the non-flat-type light diffusion adhesive layer, since the spectral characteristics are not specifically adjusted, the characteristics that the transmittance is increased as the wavelength is made longer is exhibited.

As indicated by 35b, with respect to the adhesive agent, the transmittance thereof is, in general, largely changed depending on the wavelength, wherein the longer the wavelength, the transmittance becomes higher.

Table 1

No.	Type of diffusion adhesive agent	Haze value (%)	Contrast	Reflectance at ON time (%)	Reflectance at OFF time (%)
1	Flat type (35a*)	78	10	14	1.3
2	Non-flat type (35b*)	78	6	9	1.5

*: correspond to the numeral of the diffusion material shown in Fig. 6

The table 1 shows the data which is obtained by comparing the light diffusion adhesive layer of the flat-type 35a and the light diffusion adhesive layer of the non-flat-type 35b with respect to the contrast, the reflectance at the ON time and the reflectance at the OFF time of the liquid crystal display. In the data of the table 1, to explain the difference of the spectral characteristics, the light diffusion adhesive layer of the flat type 35a and the light diffusion adhesive layer of the non-flat type 35b have the same haze value H of 78 %. As can be clearly understood from the table 1, the light diffusion adhesive layer of the flat type 35a which exhibits the spectral characteristics which is closer to the spectral characteristics of the reflecting layer 2 exhibits the more improved contrast and reflectance at the ON time of the liquid crystal display device than the light diffusion adhesive layer of the non-flat type 35b. Although the reflectance at the OFF time of the optical diffusion adhesive layer of the flat type 35a is slightly lower than that of the light diffusion adhesive layer of the non-flat type 35b, to the contrary, the lower the reflectance at the OFF time, the sinkage of the black display is deepened so that the contrast becomes higher.

Further, in the above-mentioned explanation, the visible light region is set to a wavelength region of 400 to 760 nm and, with respect to the light diffusion adhesive layer of the flat type, the transmittance or the reflectance is set within ± 10 % in the visible light region. Further, the contrast C can be defined by a following formula 2, wherein the brightness at the time of maximum gray scale display is set to Von and the brightness of the minimum gray scale display is set to Voff in the liquid crystal display.

$C = V_{on} / V_{off}$ ... formula 2

According to this embodiment, since the adhesive agent 11a having the light diffusion function is used as the light diffusing layer, by adjusting the material of the adhesive agent 17 and the diffusion material 16, the dispersion density of the diffusion material 16 and the particle diameter d of the diffusion material 16, it becomes possible to make the transmission spectral characteristics of the light diffusion adhesive layer 11a match the reflection spectral characteristics of the reflecting layer 2 so that the liquid crystal display device exhibiting the high reflectance as well as the high contrast can be provided.

According to studies carried out by inventors of the present application, the inventors have obtained a result that the smaller the refractive indices of the light diffusion material 16 and the adhesive agent 17, or the smaller the diameter d of the light diffusion material 16, the spectral characteristics of the light diffusion adhesive layer 11a becomes flatter. However, when the refractive indices of the light diffusion material 16 and the adhesive agent 17 are made small or the diameter d of the light diffusion material 16 is made small, the display characteristics such as the contrast or the like is deteriorated so that there exists a limit with respect to setting these parameters at low values.

Further, both of the first optical retardation plate 12c and the second optical retardation plate 12d can be constituted of films made of organic resin such as polycarbonate, polyacrylate, polysulfone or the like.

In this manner, according to this embodiment, since the light diffusion adhesive layer 11a is interposed between the first optical

retardation plate 12c and the second optical retardation plate 12d which exhibit small difference in thermal expansion coefficient, even when a thermal shock is applied to the liquid crystal display, there is no possibility that cracks occur in the light diffusion adhesive layer 11a and the first optical retardation plate 12c is pealed off from the second optical retardation plate 12d. In this embodiment, the first optical retardation plate 12c is also called a phase difference compensation plate and is served for preventing the display by the liquid crystal layer 9 from being colored with a specific color thus enabling the white color display.

Further, the second optical retardation plate 12d is also called a quarter-wave plate and is served for converting the reflection light L2 of elliptic polarization reflected on the reflecting layer 2 into linear polarization so as to facilitate the transmission of the reflection light L2 and the diffusion light L3 through the polarizer 12b. That is, the second optical retardation plate 12d is provided for enhancing the reflectance of the liquid crystal display.

«Driving method of liquid crystal display panel»

Further, in this embodiment, the control of the display using the specific pixel 4a is performed in a twist nematic (TN) mode or a super twist nematic (STN) mode. The liquid crystal layer 9 uses twist nematic liquid crystal in the TN mode and the liquid crystal layer 9 uses super twist nematic liquid crystal in the STN mode.

In the liquid crystal layer 9, the optical characteristics such as birefringence or the like is changed due to an electric field generated by the upper electrode 8 and the lower electrode 4. The liquid crystal display

adopting the TN mode or the STN mode can control the display thereof in such a manner that by observing the liquid crystal layer 9 through the polarizer 12b, the change of the optical characteristics of the liquid crystal layer 9 is displayed in the state (ON) which allows the transmission of light and in the state (OFF) which does not allow the transmission of light.

As a method for selecting the specific pixel 4a, this embodiment adopts a voltage equalizing method (multiplex driving method). A plurality of signal electrodes (lower electrodes) 4 are mounted on the first substrate 1 such that the signal electrodes are extended in the first direction, while scanning electrodes (upper electrodes) 8 are mounted on the second substrate 5 such that the scanning electrodes are extended in the second direction different from the first direction (the direction which is perpendicular to the first direction, for example). In a plan view, the signal electrodes 4 and the scanning electrodes 8 intersect each other in a matrix array. A portion where the signal electrode 4 and the scanning electrode 8 intersect corresponds to one pixel and the specific pixel electrode 4a can be selected by applying a selective voltage to the signal electrode 4 and the scanning electrode 8 corresponding to the specific pixel electrode 4a. To control the ON, OFF of the selected pixel, a gray scale voltage which corresponds to the ON, OFF is applied to the signal electrode 4 together with the selective voltage.

«Relationship of optical axes between liquid crystal display panel and various optical films»

An angle which is made by an elongation axis (optical axis) of the second optical retardation plate 12d which is in contact with the second

substrate 5 and an orientation axis of the liquid crystal at the irradiation light side is set in a range of 30° to 80°, an angle which is made by an elongation axis (optical axis) of the first optical retardation plate 12c which is in contact with the polarizer 12b side and an orientation axis of the liquid crystal layer 9 at the irradiation light side is set in a range of 60° to 130°, an angle which is made by an absorption axis (optical axis, polarization axis or elongation axis) of the polarizer 12b and the orientation axis of the liquid crystal layer 9 at the irradiation light side is set in a range of 70° to 150°, an angle which is made by the orientation axis of the liquid crystal layer 9 at the irradiation light side and the orientation axis of the liquid crystal at the incident light side is set to not less than 240 degrees, the retardation $\Delta n \cdot d$ of the liquid crystal layer 9 is set to 0.7 μm to 0.95 μm, the retardation $\Delta n \cdot d$ of the second optical retardation plate 12d is set to 130 nm to 250 nm, and the retardation $\Delta n \cdot d$ of the first optical retardation plate 12c is set to 380 nm to 500 nm, whereby the display exhibiting the high contrast can be obtained.

Fig. 7 is a view which specifically explains the relationship of angles among the absorption axis of the polarizer, the elongation axis of the first optical retardation plate and the elongation axis of the second optical retardation plate. Fig. 7 is explained taking the liquid crystal in the STN mode as an example.

In Fig. 7, e-e is a reference line and indicates, to be more specific, a line which is parallel to a long side of the second substrate 5 of the liquid crystal display panel and f-f indicates a line perpendicular to the e-e line. Numeral 36 indicates the irradiation-light side orientation axis of the liquid crystal layer 9, numeral 37 indicates the incident-light side orientation axis

of the liquid crystal layer 9, numeral 38 indicates the absorption axis of the polarizer 12b (optical axis of the polarizer), numeral 39 indicates the elongation axis of the first optical retardation plate 12c (optical axis of the first optical retardation plate) and numeral 40 indicates the elongation axis of the second optical retardation plate 12d (optical axis of the second optical retardation plate).

Numeral 41 indicates an angle made by the absorption axis of the polarizer and the line e-e which is specifically set to 125 ± 10°, numeral 42 indicates an angle made by the elongation axis 39 of the first optical retardation plate and the line e-e which is specifically set to 108 ± 10°, numeral 43 indicates an angle made by the elongation axis 40 of the second optical retardation plate and the line e-e which is specifically set to 72 ± 10°, numeral 44 indicates an angle made by the irradiation-light side orientation axis 36 and the incident-light side orientation axis 37 (twist angle of the liquid crystal display panel) which is set to not less than 240° in the liquid crystal display adopting the STN mode, and numeral 45 indicates an angle made by the irradiation-light side orientation axis 36 and the line e-e which is specifically set to (360 – twist angle 44) / 2 [°]. In the TN mode, the twist angel 44 may be set to 90 ± 10°. When this embodiment adopts the liquid crystal in the STN mode, a sufficient contrast can be obtained even when the number of the scanning lines 8 is increased so that the display of high definition can be obtained.

The display characteristics of the liquid crystal display which are obtained by setting the relationship among the optical axes in this embodiment to the above-mentioned relationship are shown in Fig. 8 and Fig.

9.

Fig. 8 is a view which shows the relationship between the combined retardation $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d and the contrast ratio. Provided that the liquid crystal display is set to the above-mentioned relationship among optical axes, by setting the sum of the retardations $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d to 613 nm, the maximum contrast ratio is obtained. Further, even when there exist the irregularities of ± 10 nm with respect to the retardations $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d, the high contrast ratio of not less than 10 can be obtained.

Fig. 9 is a view which shows the relationship between the combined retardation $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d and the reflectance. Provided that the liquid crystal display is set to the above-mentioned relationship among the optical axes, by setting the sum of the retardations $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d to 613 nm, the maximum reflectance can be obtained. Further, even when there exist the irregularities of ± 10 nm with respect to the retardations $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d, the high reflectance of not less than 15 % can be obtained.

Accordingly, by optimizing the relationship between the liquid crystal display panel and the optical axes of the various optical films, even when the characteristics (retardation $\Delta n \cdot d$, for example) of the various optical films are fluctuated, the high contrast ratio and the high reflectance

can be maintained and hence, it becomes possible to provide the liquid crystal display having the high manufacturing yield.

In this embodiment, as the measuring method of the retardations $\Delta n \cdot d$ of the first optical retardation plate 12c and the second optical retardation plate 12d, a spectroscopy is used. For example, the optical retardation plate which constitutes an object to be measured is sandwiched between the first and second polarization films which make their respective polarization axes intersect each other and the optical axis of the object to be measured is arranged such that the optical axis makes an angle of 45° with respect to the polarization axes of the first and second polarization films, and the spectral characteristics of light which passes or transmits the object to be measured and the first and second polarization films is measured. The spectral characteristics of the object to be measured and the first and second polarization films exhibit the minimum value (valley value) of transmittance at a specific wavelength λ and hence, the retardation $\Delta n \cdot d$ of the object to be measured can be obtained by measuring the specific wavelength λ at this point of time. Here, the first optical retardation plate 12c is measured using a single sheet of the first optical retardation plate 12c. However, with respect to the second optical retardation plate 12d, the measurement is difficult when a single sheet of the second optical retardation plate 12d is used. Accordingly, the wavelength $\lambda 2$ which corresponds to the valley value of the three sheets of second optical retardation plates 12d which are overlapped is measured and the mean value which is obtained by dividing the wavelength $\lambda 2$ in 1/3 is used.

«Whole constitution of liquid crystal display»

An example which embodies this embodiment more specifically is shown in Fig. 4a, Fig. 4b, Fig. 4c, Fig. 4d, Fig. 4e, Fig. 5a, Fig. 5b, Fig. 5c and Fig. 5d.

Fig. 4a is a front view showing a liquid crystal display 46 from a display side after completing the assembly of the liquid crystal display 46, Fig. 4b is a front side view, Fig. 4c is a rear side view, Fig. 4d is a left side view and Fig. 4e is a right side view.

In Fig. 4a to Fig. 4e, numeral 18 indicates an upper case (shielding case) which is made of a metal plate such as stainless steel, iron, aluminum or the like, numeral 20 indicates a first opening which constitutes a display window formed on the upper case 18. Numeral 19 indicates a lower case which is made of a metal plate such as stainless steel, iron, aluminum or the like or plastic such as polycarbonate, ABS resin or the like.

Numeral 21 indicates pawls which are formed on the upper case 18 and numeral 22 indicates hooks which are formed on the upper case 18, wherein the upper case 18 is pressed to the lower case 19 and is connected with the lower case 19 by means of the pawls 21 and the hooks 22.

Numeral 14 indicates a light source such as a fluorescent lamp, a LED (Light Emitting Diode) or the like. Numeral 13 is a light guide body which is made of transparent material such as acrylic resin, glass or the like and is served for irradiating the light of the light source 14 to the liquid crystal display panel. The light source 14 and the light guide body 13 constitute an illumination device (front light) which is served for supplying light to the liquid crystal display 46 when the external light is small.

Numeral 15 indicates an input device (touch panel) which is served

for inputting data to be transmitted to a host computer (information processing part) which is connected to the liquid crystal display 46.

Numeral 12 indicates optical films such as a light diffusing layer 11a, a polarization layer 12b, a first optical retardation plate 12c, a second optical retardation plate 12d and the like which are mounted on a display part of the liquid crystal display 46. To make the thickness of the liquid crystal display 46 thin, the optical films 12 are formed such that they are accommodated in the inside of a region of the first opening of the upper case.

Fig. 5a is a cross-sectional view taken along a cut line A-A of Fig. 4a, Fig. 5b is a cross-sectional view taken along a cut line B-B of Fig. 4a, Fig. 5c is a cross-sectional view taken along a cut line C-C of Fig. 4a and Fig. 5d is a cross-sectional view taken along a cut line D-D of Fig. 4a.

The liquid crystal display panel (liquid crystal cell) is constituted by laminating a first substrate 1 and a second substrate 5. Sealing members 31 which seal injection openings after injecting a liquid crystal layer 9 into the liquid crystal cell are formed on side walls of the first substrate 1 and the second substrate 5. Second openings 23 are formed in the upper case 18 at portions corresponding to the sealing members 31 such that the contour dimension of the liquid crystal display can be made small even when the sealing members 31 are protruded. The respective optical films 12 which are explained previously are fixedly secured to an outside surface (upper surface) of the second substrate 5. On the peripheries of the first substrate 1 and the second substrate 5, a drive circuit of the liquid crystal display panel which is constituted of a printed circuit board for driving scanning lines (scanning line driving PCB) 30, a scanning line driving IC chip 28, a

flexible printed circuit board (TCP) 29, a signal line driving IC chip 32 and a printed circuit board for driving signal line (signal line driving PCB) 33 is mounted. A signal line driving circuit is constituted of the signal line driving IC chip 32, the TCP 29 and the signal line driving PCB 33 and this signal line driving circuit is connected to the signal line 4 of the first substrate 1.

A scanning line driving circuit is constituted of the scanning line driving PCB 30, the scanning line driving IC chip 28 and the TCP 29. In a matrix-type liquid crystal display which uses a voltage equalizing method, the scanning line driving circuit is connected to the scanning signal line 8 of the second substrate 5. In a liquid crystal display which uses a thin film transistor (TFT), since the scanning line is mounted on the same first substrate 1 on which the signal line is mounted, the scanning line driving circuit is connected to the first substrate 1. Numeral 24 indicates an interface connector which is served for electrically connecting the liquid crystal display 46 to a host computer 50 which constitutes an external circuit. Although the interface connector 24 is mounted on the scanning line driving PCB 30 in this embodiment, the interface connector 24 may be mounted on the signal line driving PCB 33. Although not shown in the drawing, the scanning line driving PCB 30 and the signal line driving PCB 33 are electrically connected to each other by means of connecting means. Numeral 26 indicates a spacer for fixing the scanning line driving circuit PCB 30. Numeral 27 indicates a spacer for pressing a connection portion between the scanning line driving circuit and the signal line driving circuit and the liquid crystal display panel and the spacer is formed of an insulation

resilient body made of rubber or the like. Numeral 25 indicates a pressure sensitive adhesive double coated tape and, for example, a tape which is produced by impregnating epoxy-based adhesive agent in a non-woven fabric may be used. In this embodiment, the liquid crystal display panel is fixed to the upper case 18 by means of the pressure sensitive adhesive double coated tape 25. Further, the pressure sensitive adhesive double coated tape 25 is also used for fixing the light guide body 13 and the input device 15 to the upper case 18. By fixing respective members using the pressure sensitive adhesive double coated tape 25 as in the case of this embodiment, the assembly of the liquid crystal display is simplified and even when respective members are erroneously fixed, they can be reproduced so that the manufacturing yield of the liquid crystal display can be enhanced. Further, the lower case 19 is provided with irregularities for pressing the liquid crystal display panel.

«Application example of the present invention»

Fig. 16 is a perspective view showing an appearance of an information processing device 47 which uses the liquid crystal display 46 of the present invention.

Numeral 48 indicates a display part of the information processing device 47, numeral 49 indicates a keyboard part of the information processing device 47, numeral 50 indicates a host for performing information processing of the information processing device 47, numeral 51 indicates a microprocessor, numeral 52 indicates a battery, numeral 53 indicates an interface cable which connects the liquid crystal display device 46 and the host computer 50, numeral 54 indicates an inverter power source for the

illumination device, numeral 55 indicates a cable which connects the inverter power source 54 and the light source 14 of the illumination device, numeral 56 indicates a pen for inputting information using the input device 15, numeral 57 indicates a pen holder for accommodating the pen 56, numeral 60 indicates a portable telephone, and numeral 61 indicates a cable for connecting a portable telephone and the information processing device 47.

According to this embodiment, the liquid crystal display 46 is mounted on the display part 48 of the information processing device 47. According to the liquid crystal display of this embodiment, the input device 15 is superposed on the display part and hence, by pressing a given portion with the pen 56 or a finger, characters 58 can be inputted or functions of software can be executed by selecting icons 59. Further, since the liquid crystal display 46 of this embodiment is of the reflection type, when the external light such as sunlight or the like is available, by turning off a switch of the inverter power source 54, the power consumption can be suppressed and hence, the consumption of the battery 52 can be reduced.

Further, according to this embodiment, the liquid crystal display 46 can be made thin, small-sized and light-weighted and hence, the information processing device 47 can be also made thin, small-sized and light-weighted.

<u>Second Embodiment</u>

Fig. 10 is a cross-sectional view of a liquid crystal display according to the second embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The second embodiment is characterized in that, as an adhesive layer which fixes a second optical retardation plate 12d to a second substrate 5, an adhesive layer 11a which has the light diffusion function is used. Other constitutions are substantially identical with those of the previously explained first embodiment.

In this embodiment, since the adhesive layer having the light diffusion function (light diffusing layer) 11a forms a layer which is closest to the reflecting layer 2 than other optical films 12 and the adhesive layer 11, a clear display having the least blur of image profile can be obtained.

In the reflection type liquid crystal display, the display is performed using light incident from various directions. For example, as shown in Fig. 10, incident light L1 and second incident light L1b which is incident at an angle different from that of the incident light L1 are reflected on the reflecting layer 2 and respectively generate reflection light L2 and second reflection light L2b. Since the irradiation angles of the reflection light L2 and the second reflection light L2b are different, the difference d2 is generated at a position where the reflection light L2 and the second reflection light L2b pass the light diffusing layer 11a. Since an observer can recognize an image by observing light diffused from the light diffused layer 11a, the difference d2 at the position where the reflection lights L2 and L2b pass the light diffusing layer 11a is recognized as the blur of the image.

However, the closer to the reflecting layer 2 the light diffusing layer 11a is positioned, the difference d2 between the positions of the reflection lights L2, L2b which pass the light diffusing layer 11a becomes narrow and hence, the blur of the image profile is reduced so that the clearer display can

be obtained.

In this embodiment, when a glass substrate is used as the second substrate 5, due to the difference of thermal expansion coefficients between the second optical retardation plate 12d and the glass substrate which constitutes the second substrate 5, cracks are liable to easily occur in the adhesive layer 11a having the light diffusion function. However, this phenomenon can be improved by selecting the materials of the adhesive agent 17 of the adhesive layer 11a and the light diffusion material 16.

Third Embodiment

Fig. 11 is a cross-sectional view of a liquid crystal display according to the third embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The third embodiment is characterized in that, as an adhesive layer which fixes a polarizer 12b to a first optical retardation plate 12c, an adhesive layer 11a which has the light diffusion function is used. Other constitutions are substantially identical with those of the previously explained first embodiment.

The polarizer 12b is generally constituted of an organic resin film made of triacetylcellulose (TAC) or the like. The first optical retardation plate 12c can be also formed of an organic resin film made of polycarbonate, polyacrylate, polysulfone or the like and hence, the difference of thermal expansion coefficient between the first optical retardation plate 12c and the polarizer 12b can be made small.

According to this embodiment, since the adhesive layer 11a having

the light diffusion function is interposed between the polarizer 12b and the first optical retardation plate 12c which can make the difference between the thermal expansion coefficients thereof small, the problem that cracks occur in the adhesive layer 11a can be obviated and hence, the reliability of the liquid crystal display can be enhanced.

In this embodiment, compared to the previously mentioned second embodiment, the light diffusing layer 11a is disposed remoter than the reflecting layer 2 and hence, the difference d3 at a position where the previously mentioned reflection lights L2, L2b pass the light diffusing layer 11a becomes large whereby the profile of the display image is liable to be easily blurred. However, by making the liquid crystal display panel and the optical films 12 thin, the blur of the profile of the display image can be suppressed.

Fourth Embodiment

Fig. 12 is a cross-sectional view of a liquid crystal display according to the fourth embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The fourth embodiment is characterized in that a reflecting layer 2 is mounted on an outside surface of a liquid crystal display panel, that is, a surface of a side of the liquid crystal panel which does not face a liquid crystal layer 9 of a first substrate. Other constitutions are substantially identical with those of the previously explained first embodiment.

In this embodiment, the liquid crystal display panel is formed by laminating the first substrate 1 and the second substrate and thereafter the

reflecting layer 2 is mounted on the liquid crystal display panel to complete the reflection-type liquid crystal display. Accordingly, the liquid crystal display panel can be commonly used with the transmission-type liquid crystal display so that the liquid crystal display panel can be manufactured in a mass production basis whereby it becomes possible to provide the reflection-type liquid crystal display having the good productivity.

In this embodiment, a thin metal plate having a good light reflectance such as stainless steel, chromium, aluminum, silver or the like is used as the reflecting layer 2 and the reflecting layer 2 is fixed to the first substrate 1 with the use of the adhesive layer 11. By using the above-mentioned metal plate as the reflecting layer 2, it becomes easy to apply a mirror finish to the reflecting layer 2 and hence, the reflectance can be enhanced.

Further, the reflecting layer 2 may be formed by vapor-depositing metal such as chromium, aluminum, silver or the like to a first substrate 1 using a sputtering method. When the reflecting layer 2 is formed by the vapor-deposited metal, the adhesive layer 11 becomes unnecessary.

Fifth Embodiment

Fig. 13 is a cross-sectional view of a liquid crystal display according to the fifth embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The fourth embodiment is characterized in that a reflecting layer 2 is mounted on an outside surface of a liquid crystal display panel, that is, a surface of a side of the liquid crystal panel which does not face a liquid

crystal layer 9 of a first substrate and an adhesive layer 11a which has the light diffusion function is interposed between the reflecting layer 2 and the first substrate 1. Other constitutions are substantially identical with those of the previously explained first embodiment and fourth embodiment.

In this embodiment, since the light diffusing layer 11a is disposed at a position closest to the reflecting layer 2, the difference of positions where reflection lights L2, L2b pass the light diffusing layer 11a which is generated by the difference of incident angles of external lights L1, L2b can be minimized so that a clear display image having a clear profile can be obtained.

Further, this embodiment can obtain, in the same manner as the fourth embodiment which has been explained previously, the advantageous effect that a liquid crystal display panel which is used in a transmission-type liquid crystal display can be also used in this liquid crystal display and the advantageous effect that a metal plate which applies a specular reflection treatment to the reflecting layer 2 can be used.

Sixth Embodiment

Fig. 14 is a cross-sectional view of a liquid crystal display according to the sixth embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The sixth embodiment is characterized in that a reflecting layer is commonly used as a signal electrode 4 and a pixel electrode 4a. That is, the signal electrode 4 and the pixel electrode 4a are formed of a reflection conductive film such as a metal film or the like. Other constitutions are

substantially identical with those of the previously explained first embodiment.

In this embodiment, since the metal film whose electric resistance is lower than that of a transparent conductive film can be used as the signal electrode 4 or the pixel electrode 4a, the supply of electricity to the signal electrode 4 and the pixel electrode 4a can be performed favorably and hence, it becomes possible to provide a liquid crystal display having high resolution which has a large number of signal electrodes 4 and pixel electrodes 4a and a liquid crystal display having a large screen with long signal electrodes 4.

As material of the signal electrode 4, a metal film such as aluminum, gold, silver, copper, molybdenum or the like is favorably used from a viewpoint of low resistivity and a metal film such as chromium, aluminum, silver or the like is preferably used from a viewpoint of the light reflectance. The metal film which is used as the signal electrode 4 can be formed by a vapor deposition method such as sputtering or the like.

Further,although not shown in Fig. 14, in this embodiment, by interposing a light diffusing layer 11a between the pixel electrode 4a and a liquid crystal layer 9, a clear display image having a clear profile can be obtained in the same manner as the fifth embodiment.

Seventh Embodiment

Fig. 15 is a cross-sectional view of a liquid crystal display according to the seventh embodiment of the present invention. Respective numerals are same as those of Fig. 1a which are explained in the previously-mentioned first embodiment.

The seventh embodiment is characterized by adopting an active

matrix liquid crystal display panel which uses switching elements such as TFTs or the like as a liquid crystal display panel.

Although the constitution of the active-matrix-type liquid crystal display panel is explained hereinafter, the constitution which is not specifically explained is identical with that of the first embodiment which has been explained previously.

In the active-matrix-type liquid crystal display panel, as shown in Fig. 15, a plurality of pixels each of which has a thin film transistor TFT1 and a pixel electrode 4a are formed on a surface of the inner side (liquid crystal side) of a first substrate 1. Each pixel is arranged in the inside of an intersecting region which is defined by two neighboring scanning signal lines and two neighboring video signal lines. The thin film transistor TFT1 is constituted of a gate electrode GT which is formed on the first substrate 1, a gate insulation film GI which is formed on the gate electrode GT, a first semiconductor layer (channel layer) AS which is formed on the gate insulation film GI, a second semiconductor layer (semiconductor layer containing impurities) r0 which is formed on the first semiconductor layer AS, and a source electrode SD1 and a drain electrode SD2 which are formed on the second conductive layer r0. Although the source electrode SD1 and the drain electrode SD2 are formed of a multi-layered conductive film consisting of r1 and r2, they may be formed of a single-layer conductive film consisting of only r1. The relationship of electrodes becomes opposite depending on the manner of applying a voltage so that SD2 can be the source electrode and SD1 can be the drain electrode. However, in the following explanation, the explanation is made by designating SD1 as the source

electrode and SD2 as the drain electrode for a convenience sake. PSV1 indicates a protective film which is formed of an insulation film which protects the thin film transistor TFT1, numeral 4a indicates the pixel electrode, ORI1 indicates a first orientation film which orients the first substrate 1 side of a liquid crystal layer 9, ORI2 indicates a second orientation film which orients the second substrate 5 side of a liquid crystal layer 9, and numeral 8 indicates an upper electrode (common electrode). BM indicates a light shielding film which shields the thin film transistor TFT1 from light. BM is also called a black matrix and also performs the function of enhancing the display contrast by performing the light shielding between the pixel electrode 4a and the neighboring pixel electrode. SIL indicates a conductive film which electrically connects the upper electrode 8 and terminals (consisting of multi-layered metal films indicated by g1, g2, r1, r2 and r3) which are mounted on the first substrate 1.

The thin film transistor TFT1 functions, as an insulation gate type field effect transistor, a switch which makes a passage between the source electrode SD1 and the drain electrode SD2 electrically conductive when a selective voltage is applied to the gate electrode GT. The pixel electrode 4a is electrically connected to the source electrode SD1, the video signal line is electrically connected to the drain electrode SD2, and the scanning signal line is electrically connected to the gate electrode. Accordingly, based on the selective voltage applied to the scanning signal line, a specific pixel electrode 4a is selected so that a gray scale voltage applied to the video signal line can be supplied to the specific pixel electrode 4a. Cst indicates a capacitive electrode which has a function of holding the gray scale voltage supplied to

the pixel electrode 4a until the next selection period.

The active-matrix-type liquid crystal display is provided with the switching element such as the thin film transistor or the like for every pixel and hence, the display is free from a problem that crosstalks are generated between different pixels so that it is unnecessary to eliminate the crosstalks by performing a particular driving such as a voltage equalizing method whereby a multi-gray scale display can be easily realized and the lowering of the contrast is prevented even when the number of scanning lines is increased.

In this embodiment, the pixel electrode 4a is constituted of a reflection metal film such as aluminum, chromium, titanium, tantalum, molybdenum, silver or the like. Further, in this embodiment, since the protective film PSV1 is interposed between the pixel electrode 4a and the thin film transistor TFT1, even when the pixel electrode 4a is enlarged so as to overlap the thin film transistor TFT1, an erroneous operation can be eliminated and a liquid crystal display having high reflectance can be realized.

This embodiment differs from the previously-mentioned first embodiment with respect to a point that this embodiment is not provided with the first optical retardation plate 12c and a third optical plate retardation plate 12e is provided for enhancing the viewing angle characteristics. The constitution of other optical film 12 is identical with the corresponding constitution of the first embodiment. The third optical retardation plate 12e is also called a viewing angle enlarging film and is provided for improving the angle dependency of the display characteristics of

the liquid crystal display by making use of the birefringence characteristics. In this embodiment, since the third optical retardation film 12e can be also formed of organic resin film such as polycarbonate, polyacrylate or polysulfon or the like, by using the light diffusion adhesive layer 11a as the adhesive layer which fixes the third optical retardation plate 12e to the second optical retardation plate 12d, the occurrence of cracks in the optical diffusion adhesive layer 11a can be prevented.

[Industrial Applicability]

The present invention is applicable to the reflection-type liquid crystal display which performs the display using the external light such as sun light or the like, when the external light is available. The present invention particularly provides the reflection type liquid crystal display which can be mounted on the display part of the portable type information processing device such as a pen-input type computer and can reduce the power consumption of the information processing device, and can make the information processing device small-sized, thin and light-weighted and has enough feasibility.